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Determining the Alpha-Ratio of Moderated Fissile Oxides

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Abstract

It has previously been shown that the α-ratio for un-moderated Pu oxides can be rapidly determined by comparing the fast neutron spectrum measured with a liquid scintillator with pure fission and (α,n) neutron spectra measured with the same liquid scintillator. In this talk we describe how this result may be extended to moderated Pu and U oxide materials by comparing the fast neutron spectra for correlated fast neutrons with the fast neutron spectrum for uncorrelated neutrons.

It was shown some time ago by Cifarelli and Hage that if the fast neutron multiplications for fission and (α,n) neutrons are assumed to be the same then the ratio of asymptotic values of the Feynman 2-neutron and 3-neutron correlation functions Y_{2F} (t) and Y_{3F}(t) will be given by:

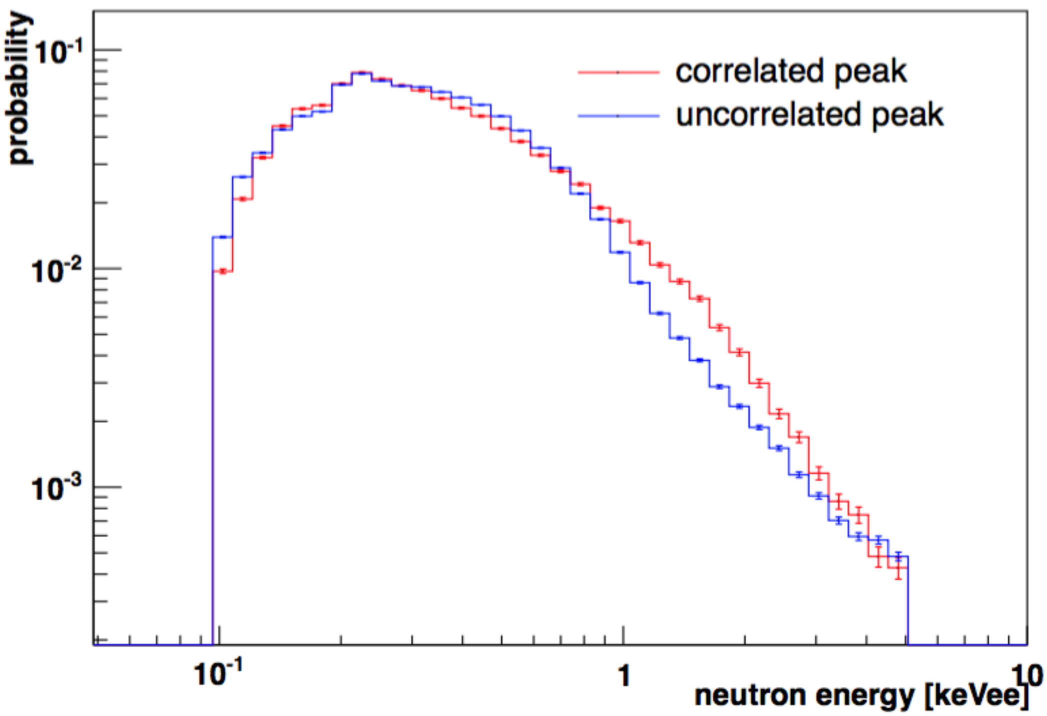
$$\frac{R_{3F}}{R_{2F}^2} = \frac{2(M-1)D_2[D_{2s}+(1+\alpha)(M-1)D_2]+D_{3s}+(1+\alpha)(M-1)D_3}{[D_{2s}+(1+\alpha)(M-1)D_2]^2}\left[1+\alpha\left(1+\frac{r=1}{M}\right)\right], \qquad (1)$$

where α is the usual parameter specifying the strength of (α,n) neutron emission relative to the rate of neutron emission due to spontaneous fission, r is the ratio of detector efficiencies for fission and (α,n) neutrons, and M is the fast neutron multiplication. If r and α are known, then Eq. 1 allows one to determine M from observed value of R_{3F}/R_{2F}^2 by solving a cubic equation. If α is not known, then additional information is needed to determine the multiplication. We have previously shown that the quantity in brackets in Eq.1 can be directly evaluated from the shape of the fast neutron spectrum. In particular fitting the fast neutron spectrum to a sum of fission and (α,n) neutron spectra yields two coefficients whose ratio ρ allows one to express the quantity in brackets in the form

$$1+\alpha\left(1+\frac{r-1}{M}\right) = \frac{(1+\alpha)(1+\rho)}{1+\rho/r} \quad . \qquad (2)$$

Substituting this expression into Eq. 1 leads to a quadratic equation for α that is readily solved if ρ and r are known. In our previous paper we showed that this method for simultaneously determining α and M in fact works quite well for samples of unmoderated PuO_2. For example, we found that for a bare 6" diameter PuO_2 ball M = 1.63 and the count rate exceeds that expected when α=0 by a factor 2.07, in good agreement with Monte Carlo predictions.

In this talk we extend our method for determining the alpha ratio for bare fissile materials to moderated fissile materials by the trick of using only the spectra of correlated neutrons to determine what the pure fission spectrum in a liquid scintillator would be. We then use the spectra of the uncorrelated fast neutrons to determine the weighted average of the fission spectrum and (α,n) neutron spectrum for the moderated sample. The figure below shows how these two spectra look for a liquid scintillator array viewing a small sample of PuO_2. It can be seen that the spectrum for the correlated peak differs significantly from the fast neutron spectrum for the uncorrelated neutrons because the spectrum for the uncorrelated neutrons includes (α,n) neutrons. This difference is largely due to the fact that the (α,n) neutron spectrum falls off faster with energy for neutron energies above a few MeV. In the talk we will show that because these differences show for multi-MeV neutrons the effect is still visible when the sample is moderated.



Acknowledgments:

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References:
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